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Do We Ignore Tobacco's Positive Ecological Role Too Long?

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ABSTRACT

Definitely, tobacco is one of the most troubling plants in this planet because of its harmful effects on humans. Therefore, tobacco plantation declines continuously in the world. For such a plant, do we need to eliminate tobacco entirely from the surface of the earth? Perhaps, humans might have ignored the tobacco's positive role in environment and ecology, especially in the heavily industrialized environments, for too long. Because the human activity generates more and more nitrogen oxides (NO_x) in atmosphere, which not only cause imbalance in the global nitrogen cycle but also lead to haze, smog, acid rain, $PM_{2.5}$, and eventually impact on environment and human health. Unfortunately the current technologies do not provide an efficient way to remove NO_x from atmosphere. However, it is only tobacco can remove NO_x from atmosphere. Perhaps, we should blame us, humans who use tobacco unwisely, rather than blame tobacco in nature. Anyways, the ability of tobacco to remove NO_2 from atmosphere should not be ignored.

1. NITROGEN OXIDES AND THEIR EFFECTS IN ENVIRONMENT

Nitrogen is one of the most abundant elements in the earth, and accounts for 78.1% of the atmosphere. Being an inert gas, nitrogen can be used by organisms only when it is converted into reactive nitrogen [1], although it is essential for all the living species. There are various forms of reactive nitrogen (Nr) in the atmosphere: ammonia (NH_3), nitrous oxide (N_2O), nitric acid (HNO_3), nitrous acid (HONO), nitrogen oxide (NO_x) including nitric oxide (NO) and nitrogen dioxide (NO_2). Thus, the nitrogen cycle, which undergoes its long-term evolution, maintains the balance of nitrogen.

It is estimated that the global nitrogen fixation generates 413 Tg N every year whereas about a half, 210 Tg N, comes from human activities. Furthermore, there are 100 Tg N into the atmosphere every year from the emissions of the NH_3 from land and the NO_x from combustion [2]. Without human activity, the

biological nitrogen fixation and the production of NO_x by lightning are the only sources for new Nr going into the environment [2]. Also, the estimated production of NO_x by lighting is about 5 Tg N ranging from 2 to 10 Tg N every year [3-8].

Due to this variability, NO_x produced by lighting would accounts for 20% - 80% of NO_x in the world [5-8]. However, the NO_x produced by lighting is located in rather remote regions of the troposphere [2]. Still, other estimates indicate that the global NO_x is about 40 Tg N in 2000, of which the combustions of fossil fuel and biomass contribute to 87.5% while the emissions of soil NO account for 12.5% [9], *i.e.* each year soil microorganisms produce 9.7 - 21 Tg N NO [10, 11]. In such a case, NO_x produced by lighting is not particularly relevant to this estimation.

Nowadays, NO_2 usually serves as the indicator for NO_x because of human activity. Indeed, NO_2 into the atmosphere comes primarily from the burning of fuel, including the emissions from cars, trucks and buses, power plants, and off-road equipment, although NO_2 contributes about 10% of NO_x and the remaining 90% NO_x is NO [11].

To some degree, the harmful effects of NO_x to humans are mainly related to NO_2. High concentrations of NO_2 irritate airways in the human respiratory system. For short exposures, NO_2 can aggravate respiratory diseases, especially asthma, and result in the respiratory symptoms, such as coughing, wheezing or difficulty breathing. For long exposures, NO_2 may affect immune functions of respiratory system leading to potential of infections as well as asthma. Furthermore, the respiratory system can be damaged by particulate matter and ozone, which are formed during the reactions among NO, NO_2 and other chemicals [13]. Some studies estimated that the health damage caused by NO_x emission accounted for 39% - 47% of the relevant health damage in China [14].

Following NO_x interaction with water, oxygen and other chemicals in the atmosphere, acid rain can be formed, which harms sensitive ecosystems such as lakes and forests. NO_x also can form the nitrate particles, which comprise the air hazy and photochemical smog leading to low visibility, ozone and other harmful substances [15]. In the atmosphere active particles are closely related to the oxidizing capacity [16]. Still, coastal waters become nutrient enrichment due to the augmentation of air NO_x. The reaction of NO_x with volatile organic compounds becomes an important precursor to increase the concentration of atmospheric $PM_{2.5}$ [17], which also contains nitrated polycyclic aromatic hydrocarbons (NPAHs) and oxygenated polycyclic aromatic hydrocarbons (OPAHs) [18].

2. REMOVAL OF NITROGEN OXIDES FROM THE ATMOSPHERE

The two common methods to reduce NO_x emissions are the selective catalytic reduction (SCR) and the selective non-catalytic reduction (SNCR), and SCR is considered the most widely-used method. Generally, SCR can remove around 90% NO_x from emissions whereas SNCR can remove about 30% - 70% NO_x from emissions. In fact, the NO_x removed by SCR and SNCR are the NO_x that has yet to enter into the atmosphere, because both SCR and SNCR are implemented in power plans, combustion engines, etc. So there is still a certain amount of NO_x passing into the atmosphere even after SCR and SNCR treatment. For example, the total emission of Nr in China has been doubled and the emission of Nr in heavily polluted areas is about 10 times of that in other areas over the last 30 years [12]. This amount of NO_x actually raises the health and environmental concerns. Currently, projected regulations for NO_x control in the US, EU and Asia define the limit of NO_x around 30 to 200 mg/NM^3.

It is generally considered that NO could be very slowly removed from the atmosphere through wet and dry deposition [2]. However, we would like to indicate that an important natural source to remove NO_x from the atmosphere has been so far ignored. This is tobacco (*Nicotiana tabacum* L.), which, to the best of our knowledge, is probably the only natural source to remove NO_x from the atmosphere although smoking is harmful to human health.

The top part in **Figure 1** shows the overall scenario for NO_x in the atmosphere, where the left-hand and right-hand sides represent the fresh air with its composition and the polluted air, respectively. The polluted air can form $PM_{2.5}$ whereas the fresh air comes from removal of NO_x from the atmosphere. In the

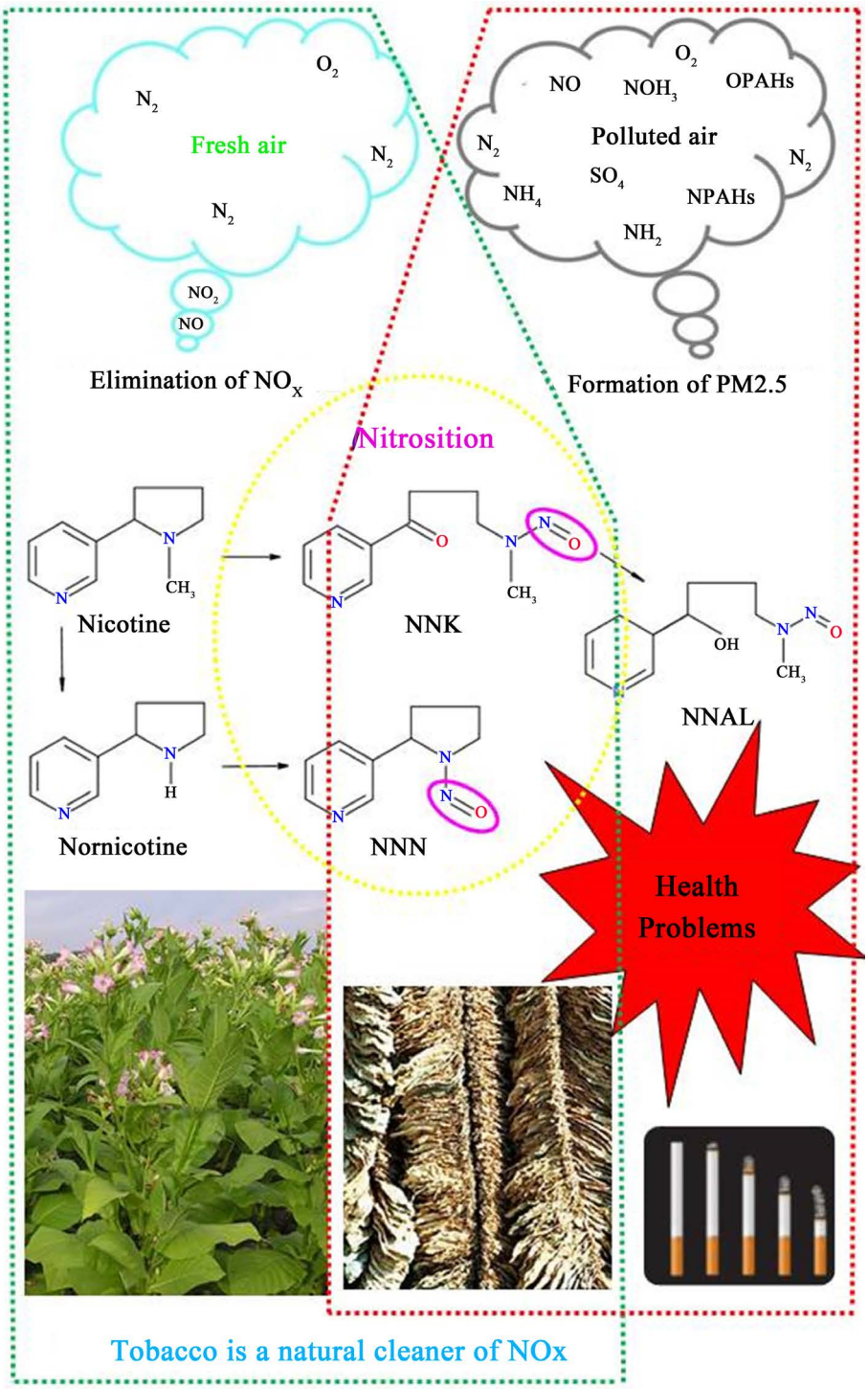

Figure 1. Tobacco's double roles in environment and human health. Yellow dashed circle indicates the nitrosation among chemical reactions in tobacco; Green dashed polygon shows tobacco effect in NO_x removal from the atmosphere; Red dashed polygon demonstrates tobacco effect in health problems.

middle of **Figure 1** shows how tobacco removes NO_x from the atmosphere through nitrosition. There are two pathways for nitrosition, 1) nicotine can directly be nitrosated into the nicotine-derived nitrosamine ketone (NNK) [19], or 2) nicotine can be demethylated into nornicotine by P450 enzymes and then nor-

nicotine can furthermore be nitrosated into N-nitrosonornicotine (NNN) [19]. The nitrosation for both nicotine and nornicotine requires a NO_2^- from environments [20] (yellow dashed circle in **Figure 1**). Thus, tobacco helps to remove NO_x from the atmosphere as indicated by green dashed polygon in the left part in **Figure 1**. This nitrosition occurs during tobacco leaves change from green to yellow (lower left-hand part of **Figure 1**) rather than during smoking (lower right-hand part of **Figure 1**), so tobacco plantation is helpful to remove NO_x from the atomosphere. On the other hand, NNN, NNK and NNAL are carcinogenic to humans [21] as indicated by red dashed polygon in the right part of **Figure 1**.

The nicotine content is about 19.63 mg/g tobacco [22] because the molar weight of nicotine is 162.23 g/mol, so 1 ton tobacco would have 19.63 kg nicotine (121 mol). If all of the nicotine would be converted to NNN/NNK, then this reaction requires 5.57 kg NO_2 (molar weight 46 g/mol), *i.e.* one-ton tobacco can absorb 5.57 kg NO_2 because the reaction consumes NO_2^- [20]. Usually, about 5% - 20% nicotine goes to NNN/NNK [19], then one-ton tobacco can absorb 0.28 - 1.10 kg NO_2. It is estimated that all smoked cigarettes produce 12,000 - 47,000 tons of nicotine annually yearly [23]. Accordingly, these amounts of nicotine could neutralize 171.17 - 670.40 tons of NO_2 in terms of 5% - 20% nicotine goes to NNN/NNK yearly.

3. EFFECTS OF DECREASED TOBACCO PLANTATION ON NO_X REMOVAL FROM THE ATMOSPHERE

Because of tobacco's harmful effects on humans, its plantation is actually decreasing year by year. For example, the tobacco plantation decreased from 1553 k hectares in 2014 to 1314 k hectares in 2015, and then further decreased to 1273 k hectares in 2016 in China. Accordingly, the tobacco production decreased from 2,994,471 tons in 2014 to 2,832,385 tons in 2015, and then further decreased to 2,725,685 tons in 2016 [24]. In fact, the tobacco production in China was 2,839,947 tons in 2008, and was peaked in 2012 with 3,408,142 tons. Since 2012, the tobacco production in China has been continuously decreasing and reached to 2,392,090 tons in 2017. Consequently, the removal of NO_x from the atmosphere also decreased, and the un-removal of NO_x should be progressively accumulated in the atmosphere because the lifetime of reactive nitrogen can range from a few weeks to few decades, even to 10^2 - 10^3 years in peatlands [15].

Figure 2 displays the accumulation of NO_x with reference to the reduction of tobacco production in China and the world since 2008. As can be seen, the tobacco production has begun to decrease in China since 2012 (red bars in lower panel), while the removal of NO_x also has begun to drop in the atmosphere since 2012 (red and black lines in upper panel). In the rest of world, the tobacco plantation decreases from 3564 k hectares in 2016 to 3529 k hectares in 2017 whereas the tobacco production increases from 6,399,092 tons in 2016 to 6,501,646 tons in 2017 [25]. So the accumulated NO_x in the atmosphere does not change significantly in contrast to China.

Due to the reduction of tobacco plantation, several hundred tons of NO_2 per year are accumulating in atmosphere each year. Naturally, this amount is not big, but the accumulated amount of NO_x over years would be significant. Indeed, it is not clear how many hectares of tobacco plantation have been terminated due to the harmful effects of tobacco since the industrial revolution. So arguably the accumulated NO_x would be a lot. Because of the harmful effect to humans, the tobacco production would be expected to continuously reduce year by year. If the tobacco production in China will reduce 5% each year, then the accumulated NO_x will reach 12,805.42 tons in 2030 (**Figure 3**).

Undeniably, the tobacco creates many healthy problems such as seven million people per year dying globally from tobacco use and exposure [26-28]. Also, tobacco industry creates environmental problems, *i.e.* deforestation [29, 30], cigarette butt waste [31-33]. However, these problems are created by humans rather than tobacco itself.

At this present, it is unknown how to remove NO_x from the atmosphere without tobacco, and then NO_x would be accumulated in the atmosphere. A point of view is that humans have no need to remove NO_x from the atmosphere because NO_x is useful to agriculture and fishery, and the elimination of NO_x emission using the current technologies generates too much CO_2 further leading to global warming [12] as the elimination of NO_x consumes equal molar ammonia, whose production generates CO_2 [34, 35].

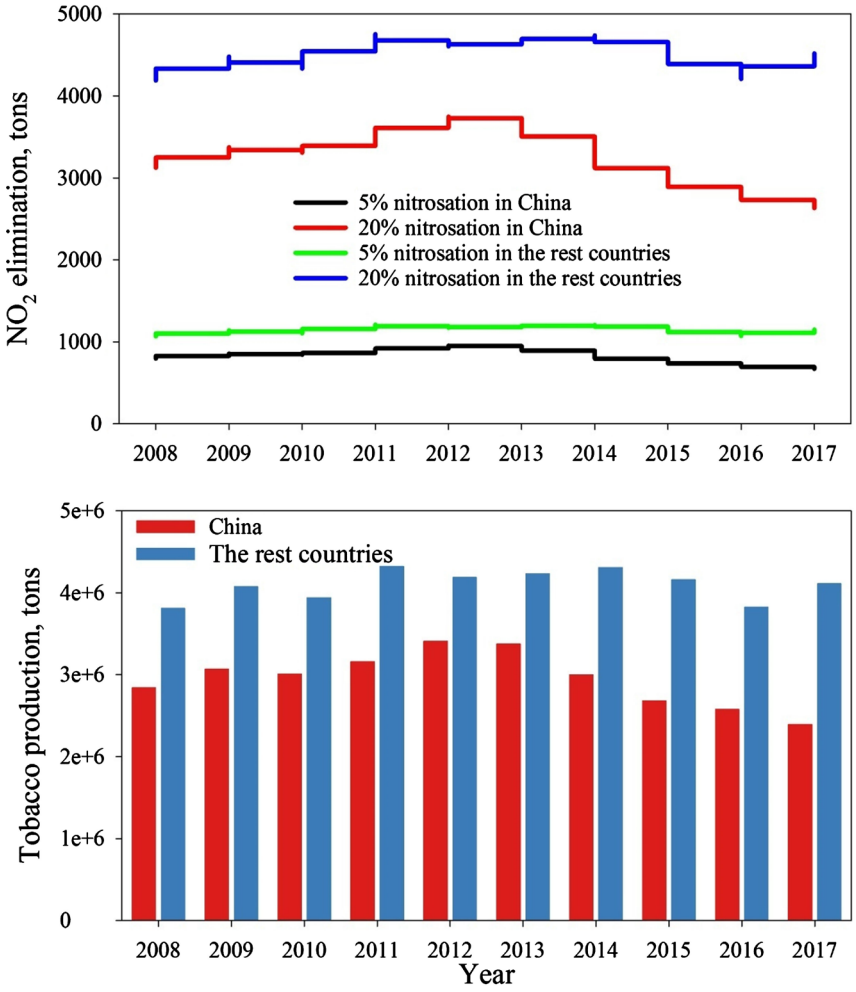

Figure 2. Tobacco production (lower panel) and related NO_2 elimination from atmosphere (upper panel) in China and the rest countries from 2008 to 2017.

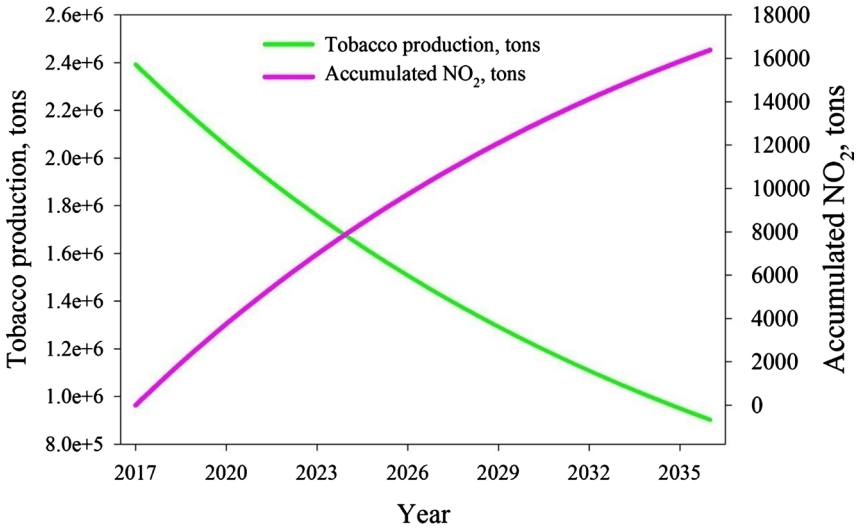

Figure 3. Predicted decrease in tobacco plantation and related accumulation of NO_2 in China from 2017 to 2036.

However, it seems not acceptable to conduct the approach not to remove NO_x from atmosphere for the sake of agriculture and fishery because NO_x do have well-known unhealthy effects on humans and unwanted pollution effects on environment and ecology.

4. CONCLUSION

Apparently, this is a dilemma: humans need to eliminate smoking for health reason through reduction of tobacco plantation, but humans also need to remove NO_x from the atmosphere also for health reason. At this point, we feel tobacco innocent when humans consider it as a killer. Ecology is such a delicate system, where nature evolves various items to balance each other. In fact, tobacco plays an important role in the balance of nitrogen cycle by removing NO_x, which generated by lighting, natural fire of biomass, and soil, from the atmosphere. Perhaps, we should blame ourselves, humans who use tobacco unwisely, rather than blame tobacco in nature. We are not in favor tobacco smoking, but its unique ability to remove NO_2 from atmosphere should not be ignored.

ETHICAL APPROVAL STATEMENT

This article does not contain any studies with human or animal participants.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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